Renewable and Sustainable Energy Reviews 16 (2012) 2200–2206

Contents lists available at SciVerse ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Roles and potentials of renewable energy in less-developed economies: The case of Nepal

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ARTICLE INFO

Article history:
Received 29 June 2011
Received in revised form 11 January 2012
Accepted 14 January 2012
Available online 18 February 2012

JEL classification:
Q42
Q01
O33

Keywords:
Renewable
Electrification
Research and development

ABSTRACT

Increasing the share of renewable energy in the national energy mix remains one of the major energy policy goals across many economies. This paper assesses the roles and potentials of renewable energy sources in less-developed economies while citing Nepal as an example. Renewable energy has a significant role to play in the electrification of rural areas in developing economies and contribute towards sustainable development. Realizing full potentials of renewable, however, requires addressing both the associated demand-side and supply-side constraints. Innovative subsidies and tax incentives, adequate entrepreneurial support, strengthening institutional arrangement and promoting local community-based organizations such as the cooperatives are the necessary factors in promoting the green technologies in countries like Nepal. International factors such as large scale investment and adequate technology transfer are equally crucial to create a rapid spread and increase affordability of decentralized renewable energy technologies in less-developed economies.

Contents

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1364-0321/$ – see front matter
doi:10.1016/j.rser.2012.01.047

1. Introduction

Renewable energy has become an integral aspect of national energy policy goals across many countries after the 1973 oil crisis even though the foundations on the economics of exhaustible resources was laid by Hotelling [1]. Often perceived as a 'backstop technology'[1] [2,3], renewable energy sources is increasingly gaining share in the national energy fuel mix across both developed and less-developing economies. While developed economies are largely supporting the non-exhaustible energy sources for strengthening security of supply and mitigating climate change impacts through reduced greenhouse gases (GHGs) emissions (see [4]); renewable energy sources provide favourable option for intensifying rural electrification and improve electricity access in less-developing economies where electricity infrastructure remains mostly centralized [5,6].

However, more than 1.4 billion people around the world still do not have access to modern energy services. Only 31% of the population in Sub-Saharan Africa has access to electricity as nine out of ten least electrified countries in the world belong to this region [7]. One of the major reasons behind a vapid progress in the rural electrification process is due to the higher costs of grid extensions in rural areas as compared to urban town and cities leading to budgetary constraints [8,9]. This is because rural areas have low load and population densities increasing the cost of marginal connection in the face of low electricity demand due to lower disposable incomes among rural customers. Many low-income household groups cannot afford to pay the upfront connections fees while the private sector lack appropriate incentives to render service to the less profitable (or rather unprofitable) and low-usage customers even though they may be willing and able to pay commercial prices for their electricity usage. Renewable technology offer suitable opportunity to electrify rural areas as the technology is capable of making better use of locally available resources, such as sunlight, biomass, wind and hydro power [10]. However, developing decentralized electricity systems from renewable energy sources can be highly costly for poor rural population to afford in the absence of any access to credit while any possibilities of cost reductions from economies of scale vanishes due to small-scale of the plants.

Renewable energy technology (RET) or the green technology comes from different sources (primarily hydro, photovoltaic, wind, geothermal, tidal, waste to energy, etc.) has a common characteristic of having large fixed costs and almost negligible variable cost. Waste-to-energy (WtE) technologies, in particular, have negative fuel cost as plants usually receive some gates fees (at least in the UK) for accepting delivery of waste while waste is usually free [11]. These technologies require significant capital expenditure before producing any energy with no added fuel cost unlike other conventional fossil based technologies which incur significant fuel costs. The average costs of renewable technologies are very much dependent on the output levels or scale with marginal cost being very low. The high upfront capital cost requirement for renewable technologies raises the levelized cost of electricity (lcoe) which is the constant price at which electricity is sold for the facility to breakeven over its lifetime as compared to other fossil fuelled power stations. Therefore, the increased deployment of renewable sources as a means to improve the electricity access rate in less developing economies largely hinges upon their ability to identify innovative mechanisms to attract both domestic and foreign capital and increase financing.

Less-developing countries are also not able to invest in energy research and development (R&D), in particular, due to resource constraints. In 1994 the average R&D expenditure as a percentage share of their GDPs was about 0.65% in developing countries and 3% in industrialized countries [6]. Investing in renewable R&D can bring the renewables 'down the cost curve' as there exists significant potential for future cost reductions due to learning [4]. However, developing economies have no culture of R&D, in particular energy R&D. R&D efforts in developing countries are primarily adaptive from technologies developed in advanced economies. Hence, the benefits from increased use of renewable technologies in less developed countries can critically depend on the technology and knowledge transfer (and the transfer rate) from advanced economies. Further, innovation diffusion only works better with policies that equally integrate the associated supply and demand-side factors [10,12–14]. However, such policies are quite rare in less-developed countries primarily due to shortage in skills and knowledge (see [15]).

The purpose of this article is to assess the potentials and role of renewables in rural electrification in less-developing countries while considering Nepal as a specific case. The paper is structured as follows. Section 2 is an overview on the current energy sector scenario in Nepal. This section discusses the existing renewable technology in the country. Section 3 analyses the demand and supply side constraints impending the spread of the renewable technologies in Nepal and other less developed countries. Finally, Section 4 concludes with relevant policy recommendations in the Nepalese context but holding general relevance to all less-developing economies in the world.

2. Energy sector scenario in Nepal

Nepal is a landlocked country in South Asia and occupies an area of 147,181 km^2 with around 28 million inhabitants. Around 82% of the total population live in rural areas and the remaining 18% resides in urban areas. The rural dominance in the country implies mass poverty as 38% of the population have disposable income of $1.25 a day and the average per capita income is $427 [16]. The country has no energy R&D culture due to resource constraints. Hence the geography, economy and the population aspects in relation to the current energy status makes Nepal a unique case study to assess the roles and potentials of renewables in less-developing countries.

The Ministry of Environment primarily looks after the development of renewable energy technologies in Nepal and has established a renewable energy subsidy policy to support these technologies. Maximising the service delivery and its efficiency in the use of renewable energy; supporting rural electrification and minimizing the electricity access gap and attracting private sector entrepreneurs remain the major objectives of the renewable energy subsidy policy [54]. As such, three broad types of energy sources exist in Nepal: commercial, traditional and alternative energy [17]. Commercial sources of energy include conventional fossil based, carbon intensive (coal and petroleum fuels) and electricity from large hydro plants that leave no footprint to the environment. Traditional energy sources include biomass contents like fuel wood, biogas, agricultural by-products and animal waste used for direct combustion. Alternative energy sources include all non-conventional forms of energy such as photovoltaic, micro-hydro, wind, biofuels, and geothermal. The total energy consumption of the country is primarily driven by traditional sources. In the Fiscal year (FY) 2008/2009, the traditional forms of energy consumption constituted 87% of total energy consumption while the remaining 13% was met through commercial and alternative energy sources [18].

[1] A backstop technology is a new technology producing a close substitute to exhaustible resources by relatively abundant product inputs and rendering the services of the exhaustible resources obsolete when the average cost of production of close substitutes falls below the spot price of exhaustible resources [2].

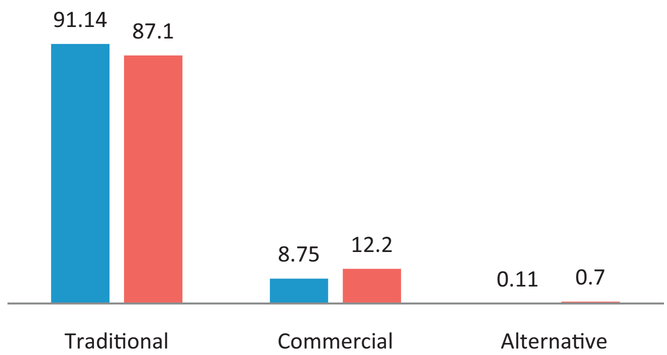


Fig. 1. Energy consumption by source type in 1995/96 (blue bar) and 2008/2009 (light brown) respectively (% of total energy consumption). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of the article.)

Nepal boasts snowy mountains (Himalayan range) in the North which acts as a perennial source for many free flowing rivers establishing the country as second richest in water resources in the world after Brazil [19]. The nation is capable of producing 40 GW of technically and economically viable commercial electricity from large hydro plants [20]. However, the vertically integrated Nepal Electricity Authority (NEA) has just managed to develop only 0.72 GW of generation capacity including that of the Independent Power Producers (IPPs). The country, being a net importer of electricity, imports 100–150 MW of electricity from India. The developments of large hydropower are rather slower than anticipated. Thus, Nepal serves as a unique case of being resource rich and policy poor in terms of hydro power generation considering its potentials [21].

Fig. 1 shows that the energy consumption pattern by source type in 2008/2009 has marginally changed as compared to 1995/1996. While fuel-wood comprised 77% of traditional energy consumption in 2008/2009 [18]; marginal increment in commercial and alternative energy usage is observed in more than a decade time period. The nation remains distinctly dependent on biomass to meet the energy demand while renewables having a negligible share in total energy consumption.

Energy consumption of traditional sources is driven by the residential sector unlike in most developed countries where the industrial sector drives the national energy consumption. In 2008/2009, the residential sector in Nepal consumed 89% of energy contributing to major exploitation of forests and deforestation in rural areas (see [18]). The transport sector consumed 5.2% of total energy (see Fig. 2) which primarily includes the fossil based petroleum products. However, the lack of any oil, gas and coal reserves in the country implies that India remains the sole supplier of commercial energy sources to Nepal [17]. Thus, a major share of export earnings is spent to import petroleum products annually and widening the bilateral trade deficit with India. Further, the irregularity in supply coupled with the rising and volatile prices of oil and gas in the international markets increases the risks of over-dependence on the imported commercial energy sources.

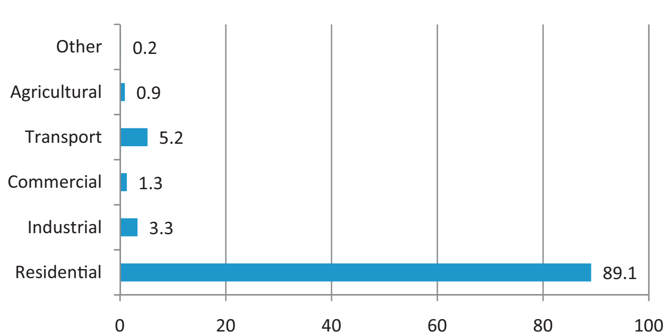


Fig. 2. Sectoral decomposition of energy consumption (% of total energy consumption).

Reliable energy supply is necessary for stimulating an export-led economic growth in Nepal as in other less-developing countries [22]. However, the 16 h daily power cut in the nation during the winter of 2008/2009 (see [55]) indicates that energy supply remains vulnerable and hampering Nepal's economic and social development. In 2010 alone, 678 GWh of energy demand was managed by load shedding [23]. The inadequate power supply in Nepal has become a critical issue as poorly managed rapid urbanization and increased growth in energy intensive industries is set to increase the national energy requirement to 9563 GWh by 2020 from the 4368 GWh in 2010 [23]. Technical losses are about 25% of power production while non-technical energy losses are also high in most South Asian countries including Nepal [24].

Having no access to modern energy services such as electricity impedes opportunities for economic development and improved living standards [25]. Around 16.5 million people currently living in Nepal are devoid of electricity and the country has an overall low score of 0.107 in terms of Human Development Index (HDI). Although the rate of electrification increased to 43.6% in 2008 as compared to 30% in 2005, the benefits of electrification are largely confined to urban areas [26]. Only 34% of rural population had access to electricity in 2008 as compared to 90% access for urban population during the same year. Moreover, the urban population is growing at 18% while the rural population growth rate stands at around 1.2%. The inability to develop large hydro-power as anticipated, increasing energy demand, constant power shortages, high technical and non-technical network losses, mass energy poverty, energy dependence and the need to improve electricity access by affordable means are the acute concerns currently evolving the Nepalese energy sector. Alternative energy sources based on decentralized production can play a significant role in mitigating these concerns and contribute towards sustainable development of the nation.

The subsections below discuss the current status of the major existing and potential renewable technologies in Nepal [27]. These technologies currently remain popular and economically feasible in the country.

2.1. *Small hydro plants*

Nepal's first major hydropower was built in Pharping with financial assistance provided by the United Kingdom (UK) in 1911. The Pharping hydropower plant had an installed capacity of 500 kW. It was followed by the construction of Trishuli hydropower plant with a capacity of 20 MW under the support from the Indian government. The presence of more than 6000 rivers (approximately 2800 miles in total length) combined with the distinct topography and unique sloppy hills provide many opportunities for small scale hydro power installation in Nepal. Small hydro facilities are classified under three categories depending upon the scale of the plants: mini hydro plants producing up to 1 MW of power, micro hydro (MH) producing up to 100 kW of energy while pico-hydro plants producing up to 5 kW of power. MH plants remain the most favored option in Nepal with the first modern facility installed four decades ago followed by many other installations in the country.

The technology is popular as micro hydro plants can provide energy for rural residential lightening as well as for industrial processes like grinding and milling in rural areas. Despite the feasibility and potentials of micro hydro plants in mass electrification; the progress has been rather slow due to affordability issues. The technology still remains costly in terms of fixed costs (or investments) although the potential for future average cost reductions can be

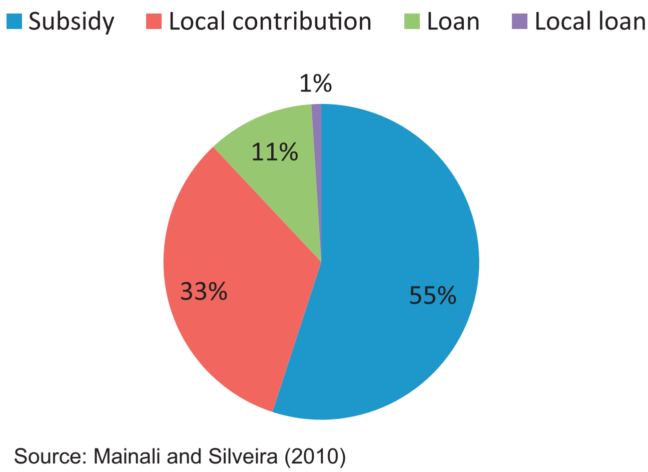


Fig. 3. Mix of financing domestic MH installations by source.
Source: Mainali and Silviera [29].

expected as the plant size grows due to economies of scale. The average cost of per kW in Nepal increased from US$ 1000 in the early 1980s to above US$ 2000 in the late 1990s [28]. A study by Mainali and Silviera [29] estimated the average cost per kW to have risen to US$ 2500 attributing the increasing costs to factor such as the increment in fixed subsidy amount per kW with the introduction of the renewable subsidy policy in 2000 and the maximum project cost ceiling enforced by the government as an eligibility criteria for subsidy approval. The costs are even higher for decentralized and remote Indian micro hydro projects in the range of US$ 2670 to US$ 5010 in the early 2000 with differences in factors such as the size of the project, quality, origin of the equipment and other market factors [30].

The average MH installation cost is US$ 264 per household in Nepal [29]. Fig. 3 provides a breakdown of the average cost structure per household in the Nepalese context. The contribution from government subsidy amounted to $144 while local community contribution was $84. Loans from external sources contributed $24 and loan from local government sources (such as village development committee) contributed $4 to the average household cost of MH installation. The significant share of community contribution indicates a high potential for the financial sustainability of MH technology towards rural electrification through popular community support in Nepal.

2.2. Solar Photovoltaic (PV)

Solar Photovoltaic is another high-profile renewable energy technology used across the country. The presence of abundant and evenly distributed sunlight implies more than 300 sunny days in a year with an average solar radiation of 3.6–6.2 kWh/m^2/day. Solar PV provides a viable option to meet electric energy demand in non-electrified rural areas in Nepal as well as meeting the growing urban demand for energy. The technology has been increasingly adopted since the installation of the first PV module in 1963 in the Bhadrapur Airport for navigational purpose [31].

According to AEPC [32], the solar PV systems in Nepal can be categorized under four broad types based on their application areas: (a) solar home system (SHS) which is defined as the household electricity supply system with solar PV panel capacity of at least 10 watts (W), battery, charge controller, and appropriate number of DC lights; (b) small solar home system (SHSH) which have a module size between 2.5 W and 10 W, battery charge controlling mechanism and white light emitting diodes; (c) community solar PV systems (CSHS) which includes solar PV powered water pumping

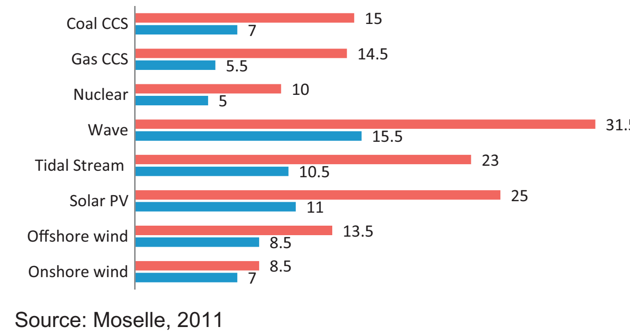


Fig. 4. Estimated 2030 levelized private cost (UK pence/kWh) with a discount factor of 10%.
Source: Moselle [4].

system and (d) institutional solar PV systems (ISPS) which includes the application of PV in public institutions such as schools, health clinics, and religious buildings. SHS remains the most popular solar PV technology in Nepal with a total number of about 115,000 installations (see [9]). As such, the residential sector has been the driving force behind the increasing adoption of PV technology in the country.

The average costs of installation of SHS in Nepal ranges from US$ 244 to US$ 880 depending upon the size of the system although the costs can be sensitive to factors like inflation and devaluation of the national currency [31]. Although the prices of SHS components are marginally falling in the international market; the price has not declined in Nepal due to lack of economies of scale as a result of small plants size; limited competition in the market and the devaluation of Nepalese currency against the US currency [33]. Loans were used to cover 55% of costs, followed by 27% subsidy and the remaining 18% was financed from owners' equity [29].

2.3. Wind power

Wind power is one of the most widely used renewable energy source around the globe, and one of the closest to being competitive with coal in terms of cost [3]. However, the utilization of wind to generate power is negligible in Nepal given the considerable potential. The theoretical potential of wind power in Nepal is estimated to be 448 MW. The potential sites for wind power systems mostly include the Mustang district as the place recorded the highest wind velocity in the country. Moreover, the nation being landlocked also eliminate the possibility to generate energy from offshore wind; a source much more powerful but comparatively costly than onshore wind.

Fig. 4 shows the levelized private costs of renewable energy technologies against low carbon fossil sources in 2030 assuming a discount factor of 10% under high cost and low cost scenarios in the UK. Onshore wind is expected to compete with cleaned coal (i.e. carbon captured and stored (CCS)) in the future followed by offshore wind. However, it faces two difficulties in competing with other low carbon energy sources: (a) intermittency as the wind does not blow all the time and (b) locational issues as many sites with strong winds could require significant investment in grid capacity expansion. Such factors can raise the levelized cost of wind electricity. However, the effect of intermittency can be negligible if wind power is used to meet a low proportion of demand as in the Nepalese context.

2.4. Geothermal

The utilization of geothermal energy in electricity production is rather unheard in the country though 32 hot water spring sites with

Table 1
Learning curves for selected energy technology.

Technology	Learning rate ignoring R&D	Learning rate controlling for R&D
Small Hydro	2.8%	0.5%
Waste to electricity (WtE)	57.9%	41.5%
Wind-onshore	15.7%	13.1%
Solar thermal power	22.5%	2.2%
Wind-offshore	8.3%	1.0%

Source: Jamasb and Kohler [53].

temperatures exceeding 50 °C had been identified in the country after 2004. Geothermal energy provides roughly 2.1 MW of energy with further development and investigation of the resource on-going. The extraction of geothermal energy is also capital intensive with no fuel costs and produces no emissions of any sort.

2.5. Costs assessment of RET

The cost assessment of renewable technologies can be a difficult process given that the average cost of renewable technologies varies greatly on scale with low marginal cost. Most cost comparisons across energy technologies are based on levelized private costs as in Fig. 4. Form a policy making perspective, it is desirable that the costs comparison is based upon levelized social costs of electricity (see [3]). The levelized cost of electricity includes the negative externalities (external costs) such as the costs of greenhouse gas emitted. While levelized social costs provide a level playing field for cost comparisons; a potentially complicating factor would be the right price of carbon which tends to vary across studies (see [34–37]).

Table 1 shows the potentials for future cost reductions of selected renewable technologies based on experience (so called learning rates) and research and development. In case of solar thermal power, wind-offshore and small hydro; a large proportion of cost reductions can come from the learning and economies of scale associated with large-scale global deployment. Hence, the sooner the countries carry out a large-scale roll out of these renewable energy sources; the faster these economies can benefit from the improved economics of these technologies. However, less developed countries like Nepal cannot afford to finance a widespread adoption of renewable technologies and spend on R&D. In 2010, the group of 20 industrialized countries (popularly termed as G-20) was responsible for 90% of investment in renewable technologies while the rest of the world only invested 10% in clean energy technology [38]. Thus, less developed countries will have to rely on the research spending as well as on the technology transfer from advanced economies to achieve any cost reductions from learning in the use of the green technologies.

Thus, Nepal like many other less developed economies exhibits a high potential for renewable energy sources which should encourage the use of renewable technologies. A study by the Netherlands Development Organization (SNV) indicates that Nepal has the theoretical potential of generating 1970 million gigajoules (GJ) of energy from known indigenous energy sources to meet and exceed all its energy needs (SNV/N, 2001). However, the empirical evidence suggests that the use of renewable technology is slower than anticipated while the high potential remains to be utilized. The next section recommends several demand and supply-side constraints to be overcome for facilitating a rapid usage of renewable technology in Nepal.

3. Addressing the demand and supply-side constraints

Technology diffusion becomes effective with policies aimed at addressing both the demand and supply factors associated. Sociological traditions leading to uncertainty and high risks perception attached with new innovation are an important demand side aspect of technology diffusion in less developed countries [39,40]. Likewise, access to financial resources and credit can be critical factors to adopt any capital intensive technologies in rural areas in less developed countries [41]. Lack of adequate supply [42] and lack of proper market infrastructure are major supply-side deterrents for widespread adoption of technology [43].

The theory of 'access gap' can further offer some guidance in the wider diffusion of renewable technology in developing countries [5,29]. The 'access gap' refers to people and location which are beyond the reach of the market due to several supply-side aspects like unfair distribution or demand-side aspects like low disposable incomes. As such, equally important are the institutional, financial, technical and managerial barriers in promoting the alternative energy technologies in less developed economies like Nepal [44]. However, several key issues need to be imminently addressed to increase the spread of the renewable energy technology in Nepal.

3.1. Designing cautious subsidies and tax incentives

The International Energy Agency (IEA) has defined energy subsidies as government support aimed at lowering the cost of energy usage through incentives to generate at a large scale and exploit economies of scale or via price reductions to consumers [45]. Hence, energy subsidy is essentially a fiscal tool to close the gap between the cost of renewable energy and the affordability of low-income households. Extending electricity access through renewable technology from well-designed subsidy and tax mechanism across the poor should maximize the social welfare in less developed economies justifying its implementation. This is because alternative carbon intensive technologies have high external costs to the society in terms of environmental damage and thereby socially less preferred to renewable technologies. Hence, subsidy is an integral source to fund renewable technology in less developed countries like Nepal (see Fig. 3).

Subsidies for MH and SHS installations were introduced in 1981/1982 and 1996/1997 respectively in Nepal. The initial subsidy design was initially based on the percentage of equipment costs which led to undesired manipulation due to costs window-dressing. The subsidy policy was thus revised and redefined in 2000 based on per kW (NRs. 70,000 or US$ 1030 per kW) generated capacity (i.e. capacity payments) to monitor the quality and estimate actual power output of the MH projects. In 2006, a new inclusive policy to enhance the electricity access for the rural poor was mooted. The policy provides additional transportation subsidy depending upon the site remoteness in relation to the nearest road head [46]. Although a policy revision would have allowed the subsidies to be reduced by 10% each year, the implementation was not possible due to several political interventions and vested interests [47]. The Nepalese subsidy scheme for solar PV is also quite attractive when compared against direct subsidies provided in other growing economies like China, Sri Lanka and Indonesia [48]. As a step further, the government can also experiment with consumption based subsidies together with the existing investment based subsidies to encourage the consumption of energy from renewable sources. Experiences from the US and Europe (in particular Germany and UK) demonstrate that feed-in tariffs (FIT) (i.e. paying consumers for the green energy they generate) can be an attractive cash-back mechanism for local and national governments to spur development of renewable energy [38].

Similarly, tax exemption/reduction schemes are also existent in Nepal as a means to bring down the fixed costs of renewable and likewise attract more investments. Commodity import duties and value added tax (VAT) are waived for green energy products like

solar panels and hydro turbines in Nepal learning from countries like India, China and Indonesia [49].

However, the existing subsidy policy in the country has not worked to the satisfaction of everyone especially due to its cumbersome delivery process [29]. The energy sector in Nepal being completely state-owned often experiences lengthy bureaucratic delays and lacks adequate transparency. While political instability in the country could be a factor, the decision making process also becomes clumsy under a centralized decision making structure [21]. The importance and sensitivity of electrification issues in less developed countries implies that the subsidies and tax policies should address the 'economic efficiency' and 'social equity' aspects of renewable electrification. While social equity can be the immediate priority economic efficiency in the long-run would ensure sustainability of the sector. This will require a time-responsive design and monitoring of the existing subsidies and tax schemes.

3.2. Improving access to (rural) credit

Renewable energy technologies being highly capital intensive but having no running cost implies that a renewable plant with 30 years lifetime is prepaid for the next 30 years. Hence, long-term debt financing seems justifiable in reducing the access gap. Start-up companies, in particular, lack sufficient capital for investment thus making the role of a loan more critical and attractive.

The Agricultural Development Bank and the National Commercial Bank have actively mobilized their capital on the renewable energy sector among the 109 banks that currently exist in Nepal. These two state-owned banks accounted for 37% of renewable loans and 98% of the loans in micro hydro, solar PV and biogas in 2008 [29]. While lack of adequate bank participation in the renewable sector is a concern, low-interest loans have often been misused and resulting in bad debts. These risks associated with bad debts can be detrimental in luring the financial institutions in green business. However, such risks and practice can be safeguarded against with adequate monitoring and may require setting up an appropriate institutional body. This will increase more banks participation allowing for new entries.

The Nepalese and Indian experiences suggest that excessive paperwork, lengthy bureaucratic procedures and stringent security requirements can be major obstacles for rural entrepreneurs in obtaining loans for renewable business [10]. Eliminating such inefficiencies in decision making is essential so that the process becomes fast-tracked. International long term loans from foreign financial institutions such as the World Bank is also equally important in less developed countries as a means to increase investment in renewable sources. However, it will require stronger arrangements towards corruption control as the country lacks adequate transparency. Low interest and well monitored loans can help in develop the market infrastructure of renewables while also provide entrepenual incentives to cash-strapped individual to invest in renewable energy.

Easy access to credit facilities can increase the adoption of renewable technologies in less developed economies like Nepal while the role of credit is crucial in minimizing the financial gap and increase affordability of green technologies.

3.3. Encouraging the private sector

The private sector being 'profit maximizers' are generally reluctant to invest in renewable energy and aid the rural electrification process as extending electricity service to the poor is unprofitable and unattractive. However, elimination of all local taxes on PV modules and complete systems coupled with eliminating import duties can increase the unit gross margins. The Indian and Indonesian experience clearly suggest that changes in tax schemes on PV modules strongly affected the rate at which start-up private enterprise expanded their sales [10]. Besides, the entry of new private players can be facilitated by creating a level playing field for both the state-owned companies and the private enterprises.

A supply-side grant per system sold as in Indonesia can be beneficial in luring the private sector and rapidly develop the market infrastructure in SHS. The experience from Bhutan suggests that public-private partnership is crucial for the development of small hydro technologies. Thus, encouraging private sector into the business is necessary to increase investment and allow for a wider adoption of renewable technologies in less developed economies like Nepal.

3.4. Proper institutional settings

The choice and use of renewable energy is contingent upon existing policy and implementing agencies at the macro-level, supply companies, dealers and financing institutions at the meso-level and local community and household economy at the micro- level [50]. The contribution of local community as a shareholder in the overall financial mix of renewable technologies is significant in less developed economies like Nepal. Thus, active involvement of local community by allowing them to manage their own power supplies is essential in harnessing locally available resources. One key aspect would be to decentralize the decision making process and let the decisions be made collectively at the local government level. However, the lack of managerial experience and subsequent social problems may necessitate a strong community mobilization and institutional capacity building at local levels.

Experiences from Bangladesh suggest that the local cooperatives can be a favourable delivery mechanism for the development of renewable energy in rural areas as socially oriented cooperatives are more inclined to contribute towards improvement in local living conditions irrespective of profit margins [51]. Thus, more focus should be towards strengthening and encouraging socially oriented community-based organizations such as cooperatives to facilitate the use of dispersed renewable sources and contribute towards the electrification of rural areas in less developed economies.

3.5. Extending adequate entrepreneurial support

Developing countries lack sufficient skills and expertise often experiencing the severe stress of human resource in governing the electricity sector [15]. Thus, it is necessary that rural companies are provided with appropriate advisory and business support services apart from the technical support. Advising on issues such as end use of electricity, accounting procedures and micro financing are important factors influencing the use of distributed energy source in rural areas. The Indian experience indicates that the establishment of 'business advisory support services' for electrification purpose in India helped in developing the managerial competence among many rural start-up companies [52]. The perceived human capital constraints among the less developed countries in the electricity sector can be addressed through training exercise, awareness programmes, and research seminars to some extent.

4. Conclusions

This article analyzed the roles and potentials of renewable energy sources in less-developed countries based on the Nepalese energy context. Less-developed countries like Nepal have significant potentials to produce electricity from locally available renewable energy sources. Harnessing energy from renewable sources can dramatically improve the electricity access in rural areas and reduce the over-dependence on traditional energy sources as well as foreign fuel imports. The larger adoption of

renewable energy technology signals a technological shift from centralized energy production and transmission towards a decentralized structure. The switch towards a decentralized production structure implies no need to engage in costly grid expansion and avoid the network energy losses. It also indicates a shift in preferences towards small-scale facilities from large-scale traditional power plants in less developed economies although economies of scale sets in as plant size increases.

Addressing the demand and supply-side constraints is necessary for the wider promotion of renewable energy technologies in less-developed economies. Both domestic and international actors will play a major role in the large scale adoption of renewable technology in less-developed countries. Domestic factors such as favourable government policies under a favourable policy environment, effective regulatory mechanisms, smart subsidies and tax incentives, indigenous innovation with required financial and institutional support can play a vital role in the widespread dissemination of renewable energy technology. The role of local community organizations such as cooperatives is crucial so adequate entrepreneurial and technical support is necessary. Similarly, increased investment in renewable energy sources from international sources in the form of well monitored long- term loans and grants coupled with timely technology transfer are essential to extend electricity services among rural-based communities in less-developed economies.

Acknowledgements

The author would like to thank Prof. Tooraj Jamasb for the guidance and support. Financial support under the James-Watt Scholarships from Heriot-Watt University is acknowledged. The author is immensely grateful to two anonymous reviewers for their helpful comments. All remaining errors belong to the author.

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